Specified Gas Emitters Regulation

Quantification Protocol For Afforestation Projects

September 2007

Version 1

Alberta
ENVIRONMENT

Disclaimer:

The information provided in this document is intended as guidance only and is subject to revisions as learnings and new information comes forward as part of a commitment to continuous improvement. This document is not a substitute for the law. Please consult the *Specified Gas Emitters Regulation* and the legislation for all purposes of interpreting and applying the law. In the event that there is a difference between this document and the *Specified Gas Emitters Regulation* or legislation, the *Specified Gas Emitters Regulation* or the legislation prevail.

Acknowledgements:

This protocol is largely based on the *Offset System Quantification Protocol for Afforestation Projects* dated July 31, 2006. Peter Graham, M.F., R.P.F., Senior Economist with the Policy, Economics and Industry Branch of the Canadian Forest Service / Natural Resources Canada was the chief developer and contact person. Peter's work represents the culmination of a multi-stakeholder consultation project and reliance on a number of guidance documents. This document represents an abridged and re-formatted version of the referenced work. Therefore, the seed document remains the source of additional detail on any of the technical elements of the protocol.

Any comments, questions, or suggestions regarding the content of this document may be directed to:

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ISBN: 978-0-7785-7214-5 (Printed)
ISBN: 978-0-7785-7215-2 (On-line)

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1.0 Project and Methodology Scope and Description

This quantification protocol is written for the afforestation project developer. Some familiarity with, or general understanding of, forestry husbandry including tree plantations is expected. Familiarity with agricultural practices and/or land conditions would also help in understanding the context of this protocol.

The opportunity for generating carbon offsets with this protocol arises mainly from carbon sequestration from planting trees on land not traditionally forested such as agricultural land, urban land, agro-forestry operations and perhaps rehabilitation of industrial lands.

1.1 Protocol Scope and Description

Given the potential range of conditions across Canada and the variety of specific activities that may be involved in afforestation projects, this protocol serves as a generic 'recipe' for proponents to follow in order to meet the measurement, monitoring and GHG quantification requirements. **FIGURE 1.1** offers a process flow diagram for a typical project.

An afforestation project will achieve GHG reductions/removals through the increase in carbon stocks (above and/or below ground and possibly soil carbon) on the project site as a result of the growth of trees. Initial carbon stocks vary, but in all cases are lower than future expected carbon stocks, both above and below ground. Emissions from the project are expected during establishment due to site preparation and planting. Other emissions following establishment will occur as a result of the maintenance required by the plantation design. These emissions are expected to be small compared to the carbon sequestered by the project.

Protocol Approach:
In practice, much of the land that will be afforested in Canada will be agricultural land (under varying degrees of management), and this protocol will cover most afforestation projects on such lands. In addition to conversion of agricultural land to treed area, the scope of this protocol may cover conversion of urban land to plantations, agroforestry, or the rehabilitation of degraded industrial lands, such as mine sites. **FIGURE 1.2** offers a process flow diagram for a typical baseline configuration.

Protocol Applicability:
It is not appropriate to apply this protocol to projects that involve planting trees on land that has recently been cleared of trees, since this does not constitute a land use change and could not be classified as afforestation. While some procedures in this protocol would be transferable to such projects, their baselines would have to incorporate any expected natural regeneration, regulatory requirements or tree cover among other possible differences in baseline and project activities.

FIGURE 1.1: Process Flow Diagram for Project Condition

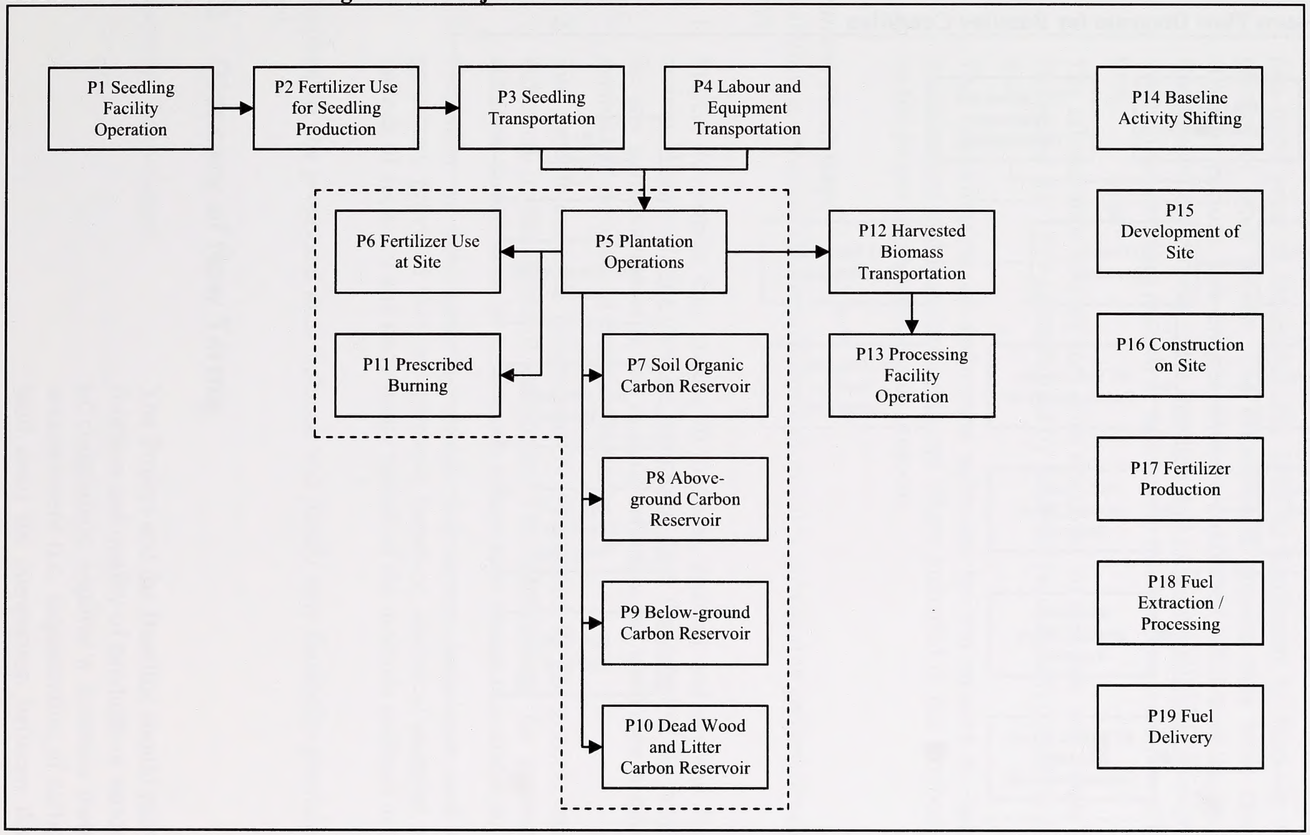
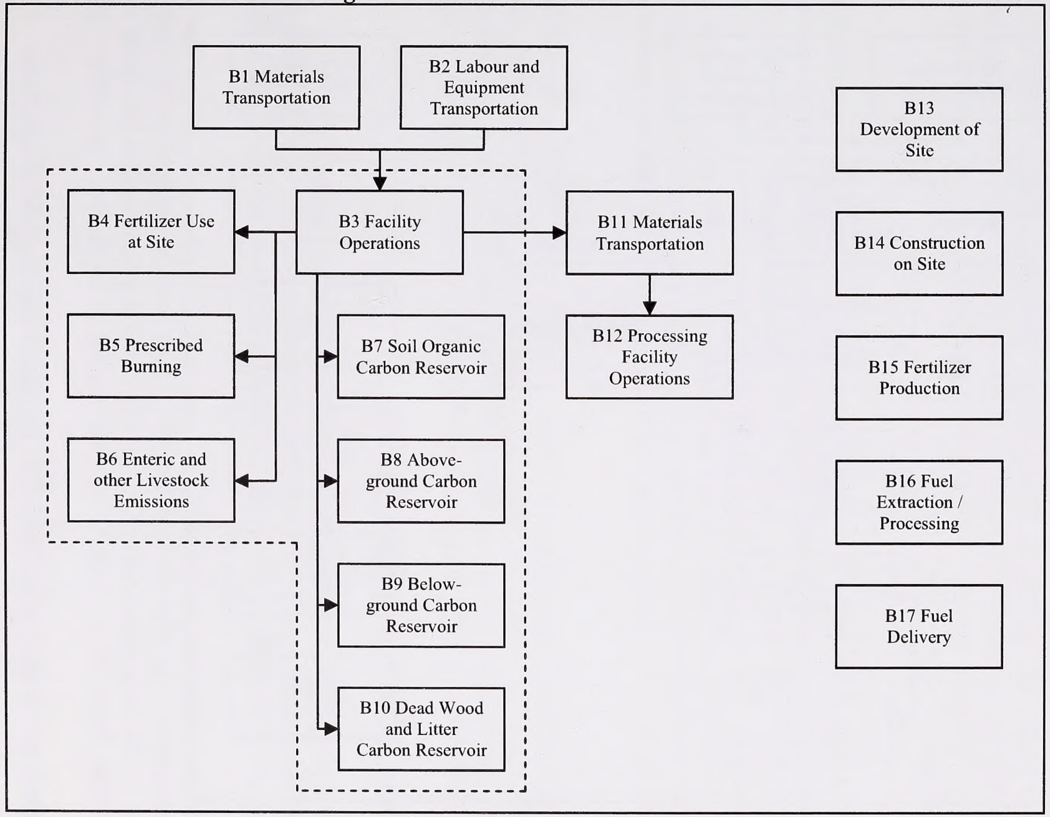


FIGURE 1.2: Process Flow Diagram for Baseline Condition



This afforestation protocol has been developed for a sub-set of afforestation projects that are considered to reflect the most common afforestation situations. To demonstrate that a project meets the requirements under this protocol, the project developer must supply sufficient evidence to demonstrate that:

1. Prior to the first year of project implementation, the afforestation project area was non-treed prior to December 31, 1989 as confirmed by land-use records, aerial photos, or other means. As afforestation projects may have extended eligible crediting periods, this criteria must be confirmed relative to the year prior to the first year of the project. This baseline will only be applicable through to the end of the eligible crediting periods at which time this baseline condition will no longer be true;
2. The afforestation project area does not cover an area that was a peat bog area after December 31, 1989 as confirmed by land-use records, aerial photos, or other means; and
3. The quantification of reductions achieved by the project is based on actual measurement and monitoring (except where indicated in this protocol) as indicated by the proper application of this protocol.

Protocol Flexibility:
Flexibility in applying the quantification protocol is provided to project developers in three ways:

1. Project developers may choose to measure, monitor and account for soil organic carbon. However, this must be completed from the outset of the project to account for any initial decreases in soil organic carbon as the treed area is established or re-established for allowed crediting periods;
2. Site specific emission factors may be substituted for the generic emission factors indicated in this protocol document. The methodology for generation of these emission factors must be sufficiently robust as to ensure reasonable accuracy; and
3. Flexibility in field sampling design and survey techniques and equipment is permitted, provided that the estimates based on statistical samples are within the bounds of accuracy and uncertainty typical of the methods outlined in this protocol.

If applicable, the proponent must indicate and justify why flexibility provisions have been used.

1.2 Glossary of New Terms

Functional Equivalence	The Project and the Baseline should provide the same function and quality of products or services. This type of comparison requires a common metric or unit of measurement (i.e. sequestration of carbon on a given land area) for comparison between the Project and

	Baseline activity (refer to the Project Guidance Document for the Alberta Offset System for more information).
Afforestation/Reforestation:	The creation of a new treed area where none existed through planting, seeding and/or the human-induced promotion of natural seed sources.
Allometric Equation:	Allometry is defined as the study and measurement of the relative growth of a part of an organism in comparison with the whole. Allometric equations can relate tree diameter at breast height (1.3 m) to other attributes such as biomass and standing carbon stock.
Assurance Factor:	The assurance factor accounts for the risk and magnitude of carbon sequestration reversal due to fire, drought, pest and other disturbances. This factor accounts for the average number of reversal events anticipated over a 20 year period. The assurance factor accounts for the reversal event across all of the years that the forest is eligible to receive credits for carbon sequestration. This prevents any liability accruing with credits for afforestation projects due to the risk of reversal.
Crediting Period	The period for which this protocol and its coefficients can be applied to a project. For more information on afforestation crediting periods and allowable cycles, see the Project Guidance Document for the Alberta Offset System.
Carbon Stock:	The absolute quantity of carbon held within a reservoir at a specified time, expressed in units of mass.
Prescribed Burn:	The knowledgeable application of fire to a specific land area to accomplish predetermined forest management or other land use objectives
Reversal:	A reduction in the amount of carbon previously stored (sequestered) in a reservoir, resulting in CO_2 emissions.
Sequestration	The process of increasing the carbon stock in a reservoir other than the atmosphere.

Tree	A woody, perennial plant generally with a single, well-defined stem and a more or less definitely formed crown. A tree is a woody plant that is usually single-stemmed and has the potential to reach a height of 5 m at maturity. This definition excludes woody shrubs but it would include agroforestry projects that include the planting of a sufficient number of trees, including fruit trees that meet the height requirements.
Treed Area	An area where the vegetation cover consists primarily of trees. Areas normally forming part of the treed area which are temporarily unstocked as a result of human intervention, such as harvesting, or as a result of natural causes, such as fire or disease, but which are expected to revert to treed areas are also included in the definition.

2.0 Quantification Development and Justification

The following sections outline the quantification development and justification.

2.1 Identification of Sources and Sinks (SS's) for the Project

SS's were identified for the project by reviewing the seed protocol document and relevant process flow diagram. This process confirmed that the SS's in the process flow diagrams covered the full scope of eligible project activities under the protocol.

Based on the process flow diagrams provided in **FIGURE 1.1**, the project SS's were organized into life cycle categories in **FIGURE 2.1**. Descriptions of each of the SS's and their classification as controlled, related or affected are provided in **TABLE 2.1.**

FIGURE 2.1: Project Element Life Cycle Chart

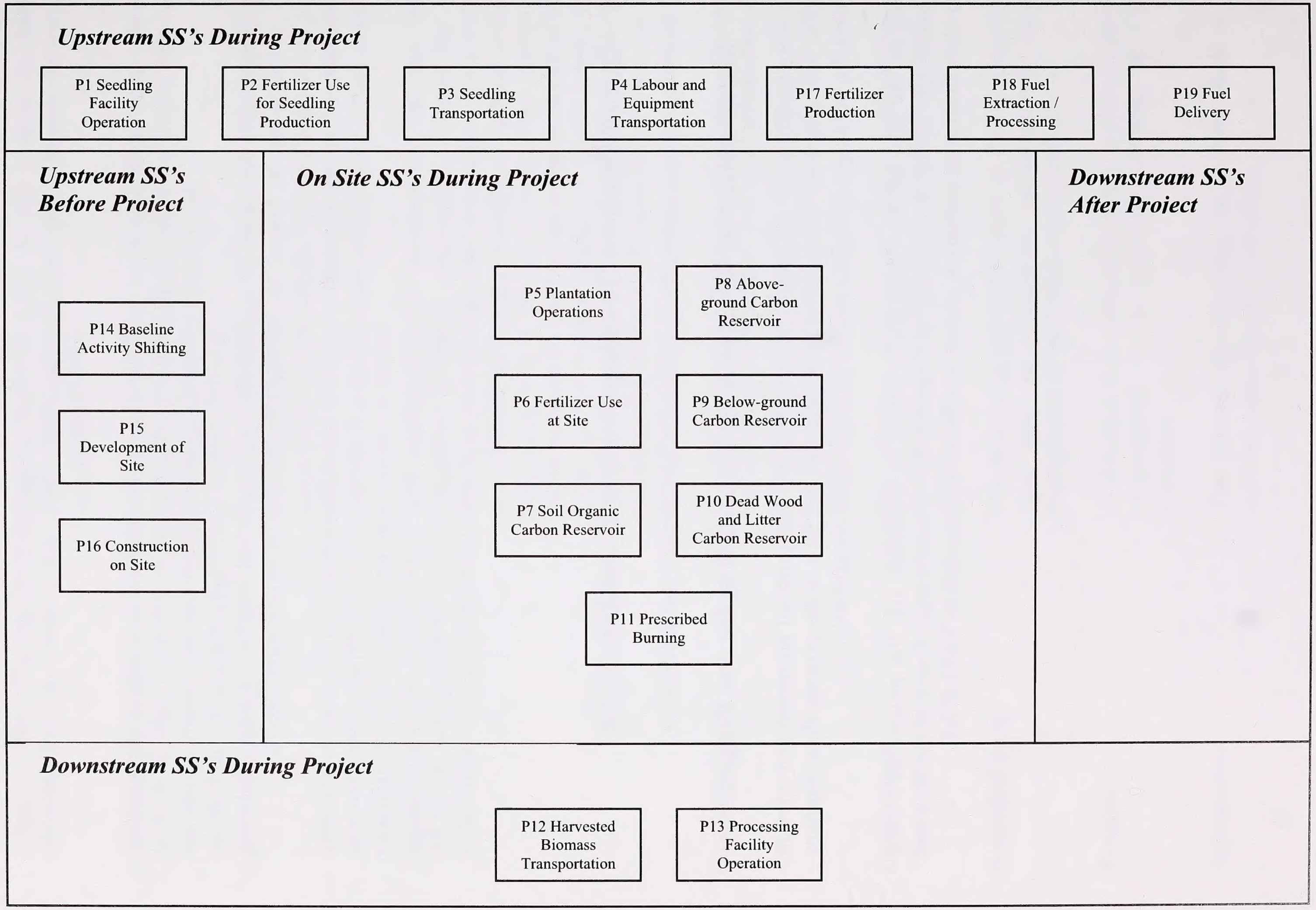


TABLE 2.1: Project SS's

1. SS	2. Description	3. Controlled, Related or Affected
Upstream SS's during Project Operation		
P1 Seedling Facility Operation	Greenhouse gas emissions may occur that are associated with the operation and maintenance of the seedling production facility. This may include running any mechanical or electrical systems. Quantities and types for each of the energy inputs would be tracked.	Related
P2 Fertilizer Use for Seedling Production	Fertilizer may be used in the seedling production process resulting in emissions of greenhouse gases, primarily N_2O. Quantities and composition of fertilizer would need to be tracked.	Related
P3 Seedling Transportation	Seedlings may be transported to the project site by truck, barge and/or train. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
P4 Labour and Equipment Transportation	Labour and equipment may be transported to the project site by truck, barge and/or train. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
P17 Fertilizer Production	Fertilizer may be produced through a number of chemical, mechanical and amendment processes. This requires several energy inputs such as natural gas, diesel and electricity. Quantities and types for each of the energy inputs would be tracked to evaluate functional equivalence with the baseline condition.	Related
P18 Fuel Extraction / Processing	Each of the fuels used throughout the on-site component of the project will need to sourced and processed. This will allow for the calculation of the greenhouse gas emissions from the various processes involved in the production, refinement and storage of the fuels. The total volumes of fuel for each of the on-site SS's are considered under this SS. Volumes and types of fuels are the important characteristics to be tracked.	Related
P19 Fuel Delivery	Each of the fuels used throughout the on-site component of the project will need to be transported to the site. This may include shipments by tanker or by pipeline, resulting in the emissions of greenhouse gases. It is reasonable to exclude fuel sourced by taking equipment to an existing commercial fuelling station as the fuel used to take the equipment to the site is captured under other SS's and there is no other delivery.	Related
Onsite SS's during Project Operation		
P5 Plantation Operations	Greenhouse gas emissions may occur that are associated with the operation and maintenance of the plantation operations. This may include running vehicles and facilities at the project site. Quantities and types for each of the energy inputs would be tracked.	Controlled
P6 Fertilizer Use at Site	Fertilizer may be used at the project site resulting in emissions of greenhouse gases, primarily N_2O. Quantities and composition of fertilizer would need to be tracked.	Controlled

P7 Soil Organic Carbon Reservoir	Carbon may be sequestered within the soil matrix. The soil carbon content would need to be tracked.	Controlled
P8 Above-ground Carbon Reservoir	Carbon may accumulate within above-ground organic materials, including biomass harvested from the site. The extent of this accumulation would need to be tracked.	Controlled
P9 Below-ground Carbon Reservoir	Carbon may accumulate within below-ground organic materials. The extent of this accumulation would need to be tracked.	Controlled
P10 Dead Wood and Litter Carbon Reservoir	Carbon may accumulate within the dead wood and litter organic materials. The extent of this accumulation would need to be tracked.	Controlled
P11 Prescribed Burning	Biomass may be combusted at the project site as part of site preparation or management. The quantity of biomass combusted would need to be tracked.	Controlled
Downstream SS's during Project Operation		
P12 Harvested Biomass Transportation	Biomass harvested from the site would need to be transported to processing facilities or end-market users. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
P13 Processing Facility Operation	Biomass harvested at the site may be processed off-site prior to being shipped to end-market users. Quantities and types for each of the energy inputs would be tracked.	Related
Other		
P14 Baseline Activity Shifting	There may be emissions associated with shifting portions of the baseline activity to another site. These are anticipated to be primarily emissions due to the transportation of livestock and equipment. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the baseline condition.	Related
P15 Development of Site	The project site may need to be prepared. This may include clearing, grading, building access roads, etc. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels used to power equipment required to develop the site such as graders, backhoes, trenching machines, etc. Quantities and types for each of the energy inputs would be tracked.	Related
P16 Construction on Site	Any construction at the site will require a variety of heavy equipment, smaller power tools, cranes and generators. The operation of this equipment will have associated greenhouse gas emission from the use of fossil fuels. Quantities and types for each of the energy inputs would be tracked.	Related

2.2 Identification of Baseline

The baseline condition is considered to be the conversion of agricultural land to a treed area, of urban land to plantations, agroforestry, or the rehabilitation of degraded industrial lands, such as mine sites.

The emissions under the baseline condition will be calculated using existing models covering the activities under the baseline condition. Given the number of years since the land may have been treed, and has since been under other land use(s) such as agriculture, it is reasonable to assume that the land would not become a treed area without the project. Therefore, the reasonable baseline scenarios range from no management activity to some degree of agricultural activity, from grazing to intensive cultivation.

Given the scope of this protocol, the soil carbon pool is the only baseline SS that is expected to change over time. However, the degree of change will be insignificant and the direction of change may alternate between sink and source over time. In addition, there is a very low likelihood of an event occurring that is beyond the control of the proponent, and that would require an adjustment of the baseline scenario.

As such, the approach to quantifying the baseline will be projection-based as there are suitable models for the applicable baseline condition that can provide reasonable certainty. The projection-based baseline scenario for this protocol is static as the emissions profile for the baseline activities would not be expected to change materially during the registration period.

The baseline condition is defined, including the relevant SS's and processes, as shown in **FIGURE 1.2**. More detail on each of these SS's is provided in Section 2.3, below.

2.3 Identification of SS's for the Baseline

Based on the process flow diagrams provided in **FIGURE 1.2**, the project SS's were organized into life cycle categories in **FIGURE 2.2**. Descriptions of each of the SS's and their classification as either 'controlled', 'related' or 'affected' is provided in **TABLE 2.2.**

FIGURE 2.2: Baseline Element Life Cycle Chart

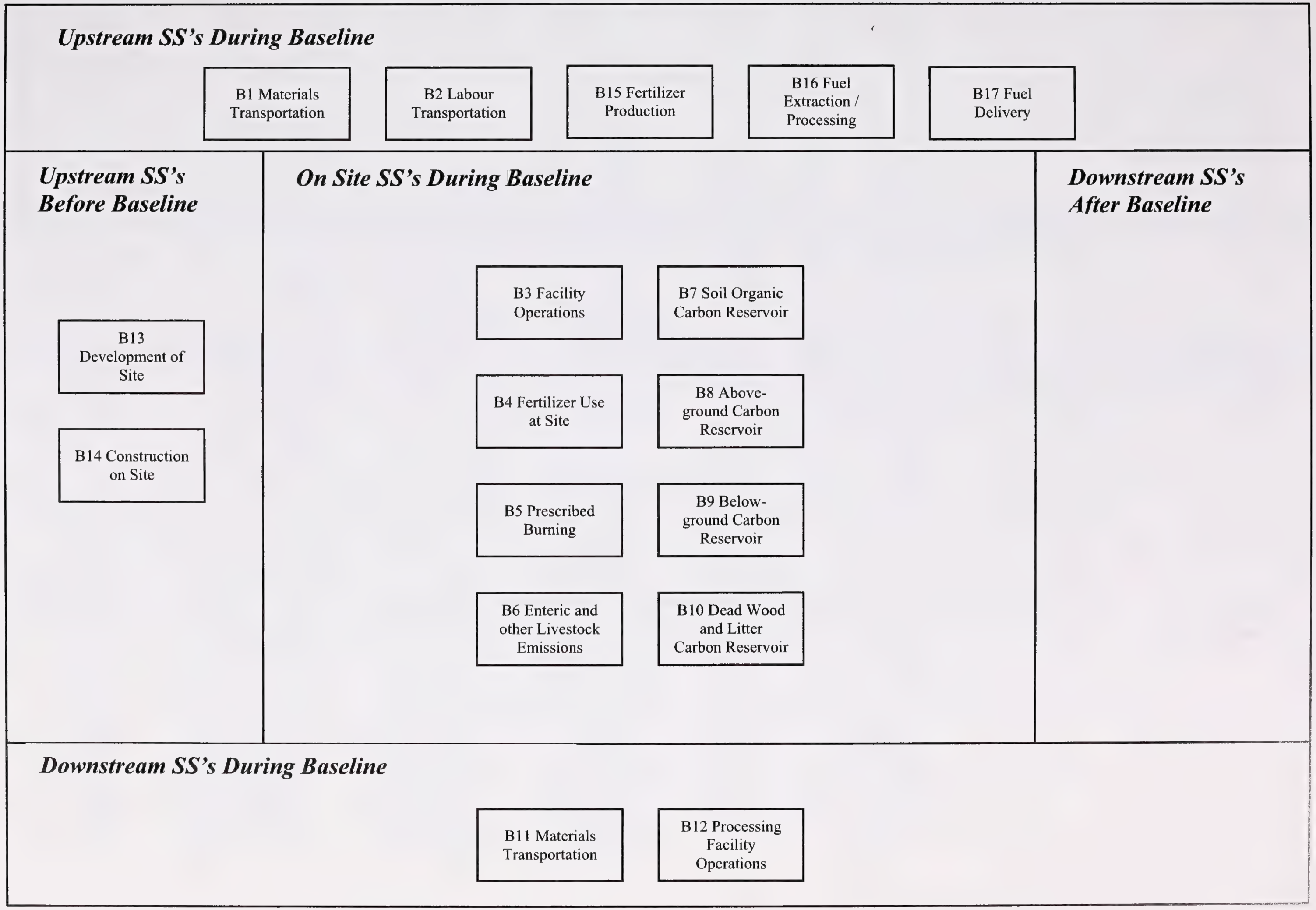


TABLE 2.2: Baseline SS's

1. SS	2. Description	3. Controlled, Related or Affected
Upstream SS's during Baseline Operation		
B1 Materials Transportation	Materials may be transported to the project site by truck, barge and/or train. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the project condition.	Related
B2 Labour and Equipment Transportation	Labour and equipment may be transported to the project site by truck, barge and/or train. The related energy inputs for fuelling this equipment are captured under this SS, for the purposes of calculating the resulting greenhouse gas emissions. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the project condition.	Related
B15 Fertilizer Production	Fertilizer may be produced through a number of chemical, mechanical and amendment processes. This requires several energy inputs such as natural gas, diesel and electricity. Quantities and types for each of the energy inputs would be contemplated and tracked to evaluate functional equivalence with the project condition.	Related
B16 Fuel Extraction / Processing	Each of the fuels used throughout the on-site component of the project will need to sourced and processed. This will allow for the calculation of the greenhouse gas emissions from the various processes involved in the production, refinement and storage of the fuels. The total volumes of fuel for each of the on-site SS's are considered under this SS. Volumes and types of fuels are the important characteristics to be tracked.	Related
B17 Fuel Delivery	Each of the fuels used throughout the on-site component of the project will need to be transported to the site. This may include shipments by tanker or by pipeline, resulting in the emissions of greenhouse gases. It is reasonable to exclude fuel sourced by taking equipment to an existing commercial fuelling station as the fuel used to take the equipment to the site is captured under other SS's and there is no other delivery.	Related
Onsite SS's during Baseline Operation		
B3 Facility Operations	Greenhouse gas emissions may occur that are associated with the operation and maintenance of the baseline facility operations. This may include running vehicles and facilities at the project site. Quantities and types for each of the energy inputs would be tracked.	Controlled
B4 Fertilizer Use at Site	Fertilizer may be used at the project site resulting in emissions of greenhouse gases, primarily N_2O. Quantities and composition of fertilizer would need to be tracked.	Controlled
B5 Prescribed Burning	Biomass may be combusted at the project site as part of site preparation or management. The quantity of biomass combusted would need to be tracked.	Controlled
B6 Enteric and other Livestock Emissions	Greenhouse gas emissions from enteric fermentation and/or other livestock related activities may result under the baseline condition. The appropriate vectors to capture the quantity of greenhouse gas emissions would need to be tracked.	Controlled
B7 Soil Organic Carbon Reservoir	Carbon may be sequestered within the soil matrix. The soil carbon content would need to be tracked.	Controlled

B8 Above-ground Carbon Reservoir	Carbon may accumulate within above-ground organic materials, including biomass harvested under the baseline condition. The extent of this accumulation would need to be tracked.	Controlled
B9 Below-ground Carbon Reservoir	Carbon may accumulate within below-ground organic materials. The extent of this accumulation would need to be tracked.	Controlled
B10 Dead Wood and Litter Carbon Reservoir	Carbon may accumulate within the dead wood and litter organic materials. The extent of this accumulation would need to be tracked.	Controlled
Downstream SS's during Baseline Operation		
B11 Materials Transportation	Materials (livestock and/or crops, etc.) from the site would need to be transported to processing facilities or end-market users. Type of equipment, number of loads and distance travelled would be used to evaluate functional equivalence with the project condition.	Related
B12 Processing Facility Operation	Materials (livestock and/or crops, etc.) from the site may be processed off-site prior to being shipped to end-market users. Quantities and types for each of the energy inputs would be tracked.	Related
Other		
B13 Development of Site	The project site may need to be prepared. This may also include clearing, grading, building access roads, etc. Greenhouse gas emissions would be primarily attributed to the use of fossil fuels used to power equipment required to develop the site such as graders, backhoes, trenching machines, etc. Quantities and types for each of the energy inputs would be tracked.	Related
B14 Construction on Site	Any construction at the site will require a variety of heavy equipment, smaller power tools, cranes and generators. The operation of this equipment will have associated greenhouse gas emission from the use of fossil fuels. Quantities and types for each of the energy inputs would be tracked.	Related

2.4 Selection of Relevant Project and Baseline SS's

Each of the SS's from the project and baseline condition were compared and evaluated as to their relevancy using the guidance provided in Annex VI of the "Guide to Quantification Methodologies and Protocols: Draft", dated March 2006 (Environment Canada). The justification for the exclusion, or conditions upon which SS's may be excluded is provided below. All other SS's listed previously are included. This information is summarized in **TABLE 2.3**, below.

TABLE 2.3: Comparison of SS's

1. Identified SS	2. Baseline (C, R, A)	3. Project (C, R, A)	4. Include or Exclude from Quantification	5. Justification for Exclusion
Upstream SS's				
P1 Seedling Facility Operation	N/A	Related	Exclude	Excluded as the market influence of afforestation projects is currently deemed to be negligible and thus there would not be any material increment in emissions under the project condition.
P2 Fertilizer Use for Seedling Production	N/A	Related	Exclude	
P3 Seedling Transportation	N/A	Related	Exclude	Excluded as the emissions from transportation are negligible and likely equivalent or lower than the baseline scenario.
B1 Materials Transportation	Related	N/A	Exclude	
P4 Labour and Equipment Transportation	N/A	Related	Exclude	Excluded as the emissions from transportation are negligible and likely equivalent or lower than the baseline scenario.
B2 Labour and Equipment Transportation	Related	N/A	Exclude	
P17 Fertilizer Production	N/A	Related	Exclude	Excluded as these SS's are not relevant to the project as the emissions from these practises are covered under proposed greenhouse gas regulations.
B15 Fertilizer Production	Related	N/A	Exclude	
P18 Fuel Extraction / Processing	N/A	Related	Exclude	Excluded as these SS's are not relevant to the project as the emissions from these practises are covered under proposed greenhouse gas regulations.
B16 Fuel Extraction / Processing	Related	N/A	Exclude	
P19 Fuel Delivery	N/A	Related	Exclude	Excluded as these SS's are not relevant to the project as the emissions from these practises are covered under proposed greenhouse gas regulations.
B17 Fuel Delivery	Related	N/A	Exclude	
Onsite SS's				
P5 Plantation Operations	N/A	Controlled	Exclude	Excluded as the emissions from site operations are likely equivalent or higher under the baseline scenario.
B3 Facility Operations	Controlled	N/A	Exclude	
P6 Fertilizer Use at Site	N/A	Controlled	Exclude	Excluded as the emissions from fertilizer use are likely equivalent or higher under the baseline scenario.
B4 Fertilizer Use at Site	Controlled	N/A	Exclude	
P11 Prescribed Burning	N/A	Controlled	Exclude	Excluded as requirements for prescribed burning for treed area management is incorporated within the assurance factor.
B5 Prescribed Burning	Controlled	N/A	Include	N/A

B6 Enteric and other Livestock Emissions	Controlled	N/A	Exclude	Excluded as it emissions are only in baseline condition and thus would only serve to increase the quantity of emission reductions achieved. As these emissions are difficult to calculate with any certainty, it is conservative to exclude them.
P7 Soil Organic Carbon Reservoir	N/A	Controlled	Exclude	Excluded as the sequestration of carbon in soil is likely to be greater in the project condition over the extended time frames of afforestation projects and would only serve to increase the quantity of emission reductions achieved. As these emissions are difficult to calculate with any certainty and direct monitoring is expensive, it is conservative to exclude them.
B7 Soil Organic Carbon Reservoir	Controlled	N/A	Exclude	
P8 Above-ground Carbon Reservoir	N/A	Controlled	Include	N/A
B8 Above-ground Carbon Reservoir	Controlled	N/A	Exclude	Excluded as carbon storage in non-tree biomass is negligible and its inclusion would serve to increase the quantity of emission reductions achieved. Thus, exclusion is a conservative approach.
P9 Below-ground Carbon Reservoir	N/A	Controlled	Include	N/A
B9 Below-ground Carbon Reservoir	Controlled	N/A	Exclude	Excluded as carbon storage in non-tree biomass is negligible and its inclusion would serve to increase the quantity of emission reductions achieved. Thus, exclusion is a conservative approach.
P10 Dead Wood and Litter Carbon Reservoir	N/A	Controlled	Exclude	Excluded as the sequestration of carbon in dead wood and litter is likely to be greater in the project condition and would only serve to increase the quantity of emission reductions achieved. Thus, exclusion is a conservative approach.
B10 Dead Wood and Litter Carbon Reservoir	Controlled	N/A	Exclude	
Downstream SS's				
P12 Harvested Biomass Transportation	N/A	Related	Exclude	Excluded as the emissions from transportation are negligible and likely equivalent or lower than the baseline scenario.
B11 Materials Transportation	Related	N/A	Exclude	
P13 Processing Facility Operation	N/A	Related	Exclude	Excluded as the emissions from the processing plants are likely negligible and equivalent or lower than the baseline scenario.
B12 Processing Facility Operation	Related	N/A	Exclude	
Other				
P14 Baseline Activity Shifting	N/A	Related	Exclude	Excluded as the emissions from shifting of baseline activities are not material given the long project life, and afforestation projects are not likely to cause large-scale shifting of activities.

P15 Development of Site	N/A	Related	Exclude	Excluded as the emissions from site development are not material given the long project life, and the minimal site development typically required.
B13 Development of Site	Related	N/A	Exclude	Excluded as the emissions from site development are not material for the baseline condition given the minimal site development typically required.
P16 Construction on Site	N/A	Related	Exclude	Excluded as the emissions from construction on site are not material given the long project life, and the minimal construction on site typically required.
B14 Construction on Site	Related	N/A	Exclude	Excluded as the emissions from construction on site are not material for the baseline condition given the minimal construction on site typically required.

2.5 Quantification of Reductions, Removals and Reversals of Relevant SS's

2.5.1 Quantification Approaches

Quantification of the reductions, removals and reversals of relevant SS's for each of the greenhouse gases will be completed using the methodologies outlined in **TABLE 2.4**, below. A listing of relevant emission factors is provided in **Appendix A**. These calculation methodologies serve to complete the following three equations for calculating the emission reductions from the comparison of the baseline and project conditions.

$$\text{Emission Reduction} = \text{Emissions}_{\text{Baseline}} - \text{Emissions}_{\text{Project}}$$

$$\text{Emissions}_{\text{Baseline}} = \text{Emissions}_{\text{Prescribed Burning}}$$

$$\text{Emissions}_{\text{Project}} = -\,((\text{Sequestration}_{\text{Above-ground Carbon Reservoir}} * \text{Assurance Factor}) + \text{Sequestration}_{\text{Below-ground Carbon Reservoir}})$$

Where:

$\text{Emissions}_{\text{Baseline}}$ = sum of the emissions under the baseline condition.
$\text{Emissions}_{\text{Prescribed Burning}}$ = emissions under SS B5 Prescribed Burning

$\text{Emissions}_{\text{Project}}$ = sum of the emissions under the project condition.
$\text{Sequestration}_{\text{Above-ground Carbon Reservoir}}$ = Sequestration under SS P8 Above-ground Carbon Reservoir
Assurance Factor = Factor which accounts for potential future reversal of sequestered carbon. Relevant assurance factors are provided in **Appendix B**.
$\text{Sequestration}_{\text{Below-ground Carbon Reservoir}}$ = Sequestration under SS P9 Below-ground Carbon Reservoir

Should the project proponent choose to monitor and quantify the sequestration of carbon in the soil, this equation is added to the other project sequestration variables. Quantification procedures are provided in **Appendix C**.

TABLE 2.4: Quantification Procedures

1.0 Project/ Baseline SS	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Method	6. Frequency	7. Justify measurement or estimation and frequency
Project SS's						
P8 Above-ground Carbon Reservoir	Sequestration $_{Above\text{-}ground\ Carbon\ Reservoir}$ = [(Incremental Vol. $_{Above\ Ground\ Tree}$ * Area $_{Afforested}$) + (Vol. $_{Biomass\ Harvested}$)]* Expansion Factor $_{Biomass}$ * Conversion Factor $_{C\text{-}CO2}$					
	Sequestration $_{Above\text{-}ground\ Carbon\ Reservoir}$	kg of CO_{2E}	N/A	N/A	N/A	Quantity being calculated.
	Volume of Above Ground Biomass Accumulating as Trees / Incremental Vol. $_{Above\ Ground\ Tree}$	m^3 / ha	Estimated	Field survey and statistical sampling with uncertainty to remain within bounds of 10%, with a confidence level of 95%.	Annual or Upon Chosen Crediting Interval	Estimation can be made with high level of accuracy.
	Volume of Above Ground Biomass Harvested / Vol. $_{Biomass\ Harvested}$	m^3	Estimated	Field survey and statistical sampling with uncertainty to remain within bounds of 10%, with a confidence level of 95%.	Annual or Upon Chosen Crediting Interval	Estimation can be made with high level of accuracy.
	Biomass Expansion Factor / Expansion Factor $_{Biomass}$	kg of Carbon per m^3	Estimated	From sources of species specific data tables.	Annual	Carbon content of trees can vary significantly between samples. Using factors based on larger samples would be more accurate.
	Area of Afforestation Project / Area $_{Afforested}$	ha	Estimated	Field survey or map-based assessment with uncertainty to remain within bounds of 10%, with a confidence level of 95%.	Annual or Upon Chosen Crediting Interval	Estimation can be made with high level of accuracy.
	Conversion factor for Carbon to Carbon Dioxide / Conversion Factor $_{C\text{-}CO2}$	-	Estimated	IPCC standard of 44/12.	Annual	Reference value.
P9 Below-ground Carbon Reservoir	Sequestration $_{Below\text{-}ground\ Carbon\ Reservoir}$ = Incremental Vol. $_{Above\ Ground\ Tree}$ * Ratio $_{Root\text{-}Shoot}$ * Expansion Factor $_{Biomass}$ * Area $_{Afforested}$ * Conversion Factor $_{C\text{-}CO2}$					
	Sequestration $_{Above\text{-}ground\ Carbon\ Reservoir}$	kg of CO_{2E}	N/A	N/A	N/A	Quantity being calculated.

	Volume of Above Ground Biomass Accumulating as Trees / Incremental Vol. $_{Above Ground Tree}$	m^3 / ha	Estimated	Field survey and statistical sampling with uncertainty to remain within bounds of 10%, with a confidence level of 95%.	Annual or Upon Chosen Crediting Interval	Estimation can be made with high level of accuracy.
	Ratio of Below-ground Biomass to Above-ground Tree Volume	-	Estimated	From sources of species specific data tables.	Annual	Ratios of below-ground biomass to above-ground tree volume can vary significantly between samples. Using factors based on larger samples would be more accurate.
	Biomass Expansion Factor / Expansion Factor $_{Biomass}$	kg of Carbon per m^3	Estimated	From sources of species specific data tables.	Annual	Carbon content of trees can vary significantly between samples. Using factors based on larger samples would be more accurate.
	Area of Afforestation Project / Area $_{Afforested}$	ha	Estimated	Field survey or map-based assessment with uncertainty to remain within bounds of 10%, with a confidence level of 95%.	Annual or Upon Chosen Crediting Interval	Estimation can be made with high level of accuracy.
	Conversion factor for Carbon to Carbon Dioxide / Conversion Factor $_{C\text{-}CO2}$	-	Estimated	IPCC standard of 44/12.	Annual	Reference value.
Baseline SS's						
B5 Prescribed Burning	Emissions $_{Prescribed Burning}$ = Area $_{Burn}$ * EF Biomass $_{CO2E}$					
	Emissions $_{Prescribed Burning}$	kgs of CH_4 and N_2O	N/A	N/A	N/A	Quantity being calculated.
	Area of Affected by Burn / Area $_{Burn}$	ha	Estimated	Field survey or map-based assessment with uncertainty to remain within bounds of 10%, with a confidence level of 95%.	Annual or Upon Chosen Crediting Interval	Estimation can be made with high level of accuracy.
	CO_{2E} Emissions Factor for Biomass / EF Biomass $_{CO2E}$	kg CO_{2E} per ha	Estimated	Reference value from IPCC.	Annual	Reference values adjusted periodically by IPCC.

2.5.2. Contingent Data Approaches

Contingent means for calculating or estimating the required data for the equations outlined in section 2.5.1 are summarized in **TABLE 2.5**, below.

2.6 Management of Data Quality

In general, data quality management must include sufficient data capture such that the mass and energy balances may be easily performed with the need for minimal assumptions and use of contingency procedures. The data should be of sufficient quality to fulfill the quantification requirements and be substantiated by company records for the purpose of verification.

The project proponent shall establish and apply quality management procedures to manage data and information. Written procedures should be established for each measurement task outlining responsibility, timing and record location requirements. The greater the rigour of the management system for the data, the more easily an audit will be to conduct for the project.

2.6.1 Record Keeping

Record keeping practises should include:

a. Electronic recording of values of logged primary parameters for each measurement interval;
b. Printing of monthly back-up hard copies of all logged data;
c. Written logs of operations and maintenance of the project system including notation of all shut-downs, start-ups and process adjustments;
d. Retention of copies of logs and all logged data for a period of 7 years; and
e. Keeping all records available for review by a verification body.

2.6.1 Quality Assurance/Quality Control (QA/QC)

QA/QC can also be applied to add confidence that all measurements and calculations have been made correctly. These include, but are not limited to:

a Protecting monitoring equipment (sealed meters and data loggers);
b Protecting records of monitored data (hard copy and electronic storage);
c Checking data integrity on a regular and periodic basis (manual assessment, comparing redundant metered data, and detection of outstanding data/records);
d Comparing current estimates with previous estimates as a 'reality check';
e Provide sufficient training to operators to perform maintenance and calibration of monitoring devices;
f Establish minimum experience and requirements for operators in charge of project and monitoring; and
g Performing recalculations to make sure no mathematical errors have been made.

TABLE 2.5: Contingent Data Collection Procedures

1.0 Project/ Baseline SS	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Contingency Method	6. Frequency	7. Justify measurement or estimation and frequency
Project SS's						
P8 Above-ground Carbon Reservoir	Volume of Above Ground Biomass Accumulating as Trees / Incremental $Vol._{Above\ Ground\ Tree}$	m^3 / ha	Estimated	Extrapolation of previous estimations over time.	Annual or Upon Chosen Crediting Interval	Applicable in cases where there is a short interval since last estimate and more than 3 previous estimates.
	Volume of Above Ground Biomass Harvested / $Vol._{Biomass\ Harvested}$	m^3	Estimated	Extrapolation of previous estimations over time.	Annual or Upon Chosen Crediting Interval	Applicable in cases where there is a short interval since last estimate and more than 3 previous estimates.
	Area of Afforestation Project / $Area_{Afforested}$	ha	Estimated	Aerial photographs.	Annual or Upon Chosen Crediting Interval	Similar estimation technique with minor increase in uncertainty.
Baseline SS's						
B5 Prescribed Burning	Area of Affected by Burn / $Area_{Burn}$	ha	Estimated	Aerial photographs	Annual or Upon Chosen Crediting Interval	Similar estimation technique with minor increase in uncertainty.

APPENDIX A:
Relevant Emission Factors

Table A1: Stand Level Biomass Expansion Factors for Different Species and Regions in Canada

Region		Species				
Province	Terrestrial Ecozone	Spruce	Pine	Hybrid Poplar	Other SW	Other HW
AB	Boreal Plains	1.20	1.05	1.08	1.09	1.26
AB	Boreal Shield West	1.09	1.09	1.11	1.09	1.11
AB	Montane Cordillera	1.21	1.20	0.95	1.18	1.26
AB	Prairies	1.09	1.09	1.11	1.09	1.26
AB	Taiga Plains	0.94	0.86	0.99	0.98	0.99
AB	Taiga Shield West	0.98	0.98	0.99	0.98	0.99
BC	Boreal Cordillera	1.34	1.26	1.67	1.36	1.35
BC	Boreal Plains	1.09	1.11	1.48	1.08	1.42
BC	Montane Cordillera	1.19	1.19	1.56	1.48	1.55
BC	Pacific Maritime	1.43	2.08	1.54	1.72	1.47
BC	Taiga Plains	1.09	0.90	1.37	1.02	1.29
MB	Boreal Plains	0.79	0.69	0.71	0.75	0.71
MB	Boreal Shield West	0.80	0.68	0.78	0.73	0.79
MB	Hudson Plains	0.73	0.73	0.79	0.73	0.79
MB	Prairies	0.75	0.75	0.71	0.75	0.71
MB	Taiga Shield West	0.73	0.73	0.79	0.73	0.79
NB	Atlantic Maritime	0.88	0.83	1.03	0.82	1.04
NL	Boreal Shield East	1.08	1.16	0.95	1.16	0.95
NL	Taiga Shield East	0.81	1.01	0.95	1.01	0.95
NS	Atlantic Maritime	0.86	1.52	0.93	0.88	1.13
NU	Hudson Plains	0.80	0.80	0.95	0.80	0.95
NU	Taiga Shield West	0.90	0.90	0.85	0.90	0.85
NT	Boreal Cordillera	0.88	0.88	0.93	0.88	0.93
NT	Boreal Plains	1.09	1.09	1.11	1.09	1.11
NT	Taiga Cordillera	0.88	0.88	0.93	0.88	0.93
NT	Taiga Plains	0.90	0.90	0.85	0.90	0.85
NT	Taiga Shield West	0.90	0.90	0.85	0.90	0.85
ON	Boreal Shield East	0.82	0.74	0.79	0.77	0.78
ON	Boreal Shield West	0.82	0.74	0.79	0.77	0.78
ON	Hudson Plains	0.80	0.80	0.95	0.80	0.95
ON	Mixedwood Plains	0.69	0.69	0.84	0.69	0.84
PE	Atlantic Maritime	0.81	0.84	0.94	0.84	1.06
QC	Atlantic Maritime	0.86	0.75	0.89	0.87	1.06
QC	Boreal Shield East	0.82	0.71	0.84	0.81	0.98
QC	Hudson Plains	0.83	0.80	0.95	0.80	0.95
QC	Mixedwood Plains	0.91	0.74	0.84	0.78	0.94
QC	Taiga Shield East	0.80	0.80	0.95	0.80	0.95
SK	Boreal Plains	0.85	0.74	0.78	0.83	0.79
SK	Boreal Shield West	0.84	0.81	0.79	0.84	0.79
SK	Taiga Shield West	0.73	0.73	0.79	0.73	0.79
SK	Prairies	0.75	0.75	0.71	0.75	0.71
YT	Boreal Cordillera	0.87	0.88	0.95	0.88	0.93
YT	Pacific Maritime	1.72	1.72	1.47	1.72	1.47
YT	Taiga Cordillera	0.88	0.88	0.93	0.88	0.93
YT	Taiga Plains	1.02	1.02	1.29	1.02	1.29

Figure A1: Terrestrial Ecozones of Canada (Environment Canada, 1996; Kull *etal.,*2006).

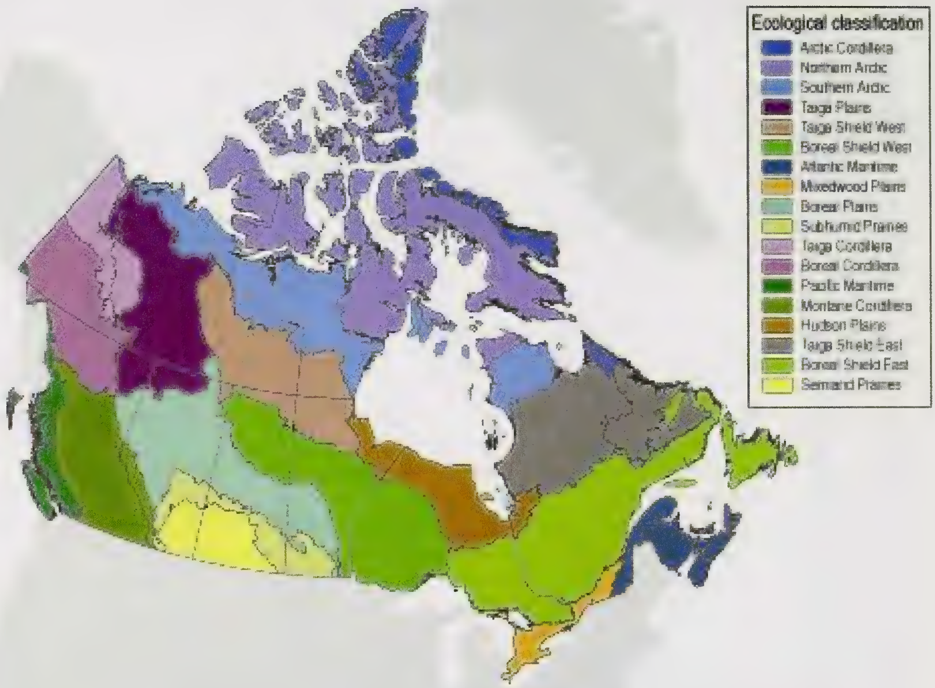


Table A2: Stand Level Root-to-Shoot Ratios for Different Species and Regions in Canada

Region		Species				
Province	**Terrestrial Ecozone**	**Spruce**	**Pine**	**Hybrid Poplar**	**Other SW**	**Other HW**
AB	Boreal Plains	0.133	0.116	0.141	0.121	0.155
AB	Boreal Shield West	0.121	0.121	0.143	0.121	0.143
AB	Montane Cordillera	0.134	0.133	0.130	0.131	0.155
AB	Prairies	0.121	0.121	0.143	0.121	0.155
AB	Taiga Plains	0.104	0.095	0.133	0.109	0.133
AB	Taiga Shield West	0.109	0.109	0.133	0.109	0.133
BC	Boreal Cordillera	0.148	0.140	0.183	0.151	0.161
BC	Boreal Plains	0.120	0.123	0.170	0.120	0.167
BC	Montane Cordillera	0.131	0.131	0.176	0.164	0.175
BC	Pacific Maritime	0.159	0.231	0.175	0.190	0.170
BC	Taiga Plains	0.120	0.099	0.163	0.113	0.157
MB	Boreal Plains	0.088	0.076	0.109	0.083	0.109
MB	Boreal Shield West	0.089	0.075	0.115	0.080	0.116
MB	Hudson Plains	0.080	0.080	0.116	0.080	0.116
MB	Prairies	0.083	0.083	0.109	0.083	0.109
MB	Taiga Shield West	0.080	0.080	0.116	0.080	0.116
NB	Atlantic Maritime	0.097	0.092	0.136	0.091	0.137
NL	Boreal Shield East	0.120	0.128	0.129	0.128	0.129
NL	Taiga Shield East	0.090	0.112	0.129	0.112	0.129
NS	Atlantic Maritime	0.096	0.168	0.128	0.097	0.145
NU	Hudson Plains	0.088	0.088	0.129	0.088	0.129
NU	Taiga Shield West	0.099	0.099	0.121	0.099	0.121
NT	Boreal Cordillera	0.097	0.097	0.129	0.097	0.129
NT	Boreal Plains	0.121	0.121	0.143	0.121	0.143
NT	Taiga Cordillera	0.097	0.097	0.129	0.097	0.129
NT	Taiga Plains	0.099	0.099	0.121	0.099	0.121
NT	Taiga Shield West	0.099	0.099	0.121	0.099	0.121
ON	Boreal Shield East	0.091	0.082	0.116	0.086	0.115
ON	Boreal Shield West	0.091	0.082	0.116	0.086	0.115
ON	Hudson Plains	0.088	0.088	0.129	0.088	0.129
ON	Mixedwood Plains	0.076	0.076	0.120	0.076	0.120
PE	Atlantic Maritime	0.090	0.093	0.129	0.093	0.139
QC	Atlantic Maritime	0.096	0.083	0.125	0.096	0.139
QC	Boreal Shield East	0.091	0.078	0.120	0.089	0.133
QC	Hudson Plains	0.092	0.088	0.129	0.089	0.129
QC	Mixedwood Plains	0.100	0.082	0.120	0.087	0.129
QC	Taiga Shield East	0.089	0.089	0.129	0.089	0.129
SK	Boreal Plains	0.094	0.082	0.115	0.092	0.116
SK	Boreal Shield West	0.093	0.089	0.116	0.093	0.116
SK	Taiga Shield West	0.080	0.0800	0.116	0.08	0.116
SK	Prairies	0.083	0.083	0.109	0.083	0.109
YT	Boreal Cordillera	0.096	0.097	0.130	0.097	0.129
YT	Pacific Maritime	0.190	0.190	0.170	0.190	0.170
YT	Taiga Cordillera	0.097	0.097	0.129	0.097	0.129
YT	Taiga Plains	0.113	0.113	0.157	0.113	0.157

Table A3: Select Density Values for a Selection of Species

Species	Density (t/m3)
Trembling aspen	0.37
Black cottonwood	0.30
Willow (US)	0.39
White birch	0.51
Sugar maple	0.60
White ash	0.57
Red oak	0.58
Black walnut	0.55
Balsam fir	0.34
Jack pine	0.42
Lodgepole pine	0.40
Ponderosa pine	0.44
Red pine	0.39
Jack pine	0.42
White pine (eastern & western)	0.36
White spruce	0.35
Douglas-fir	0.45
Western larch	0.55
Western red cedar	0.31
Tamarack	0.48
Other softwoods and hybrid poplars	0.37
Other deciduous hardwoods	0.60

Table A4: Miscellaneous Factors

Parameter	Density (t/m3)
Mass of Carbon per Mass Dry Biomass	0.5
Mass of Above-ground Biomass per Mass of Merchantable Biomass	1.45

APPENDIX B:
Relevant Assurance Factors

Development of Assurance Factors

The assurance factor accounts for the average risk of reversal across all afforestation projects within a given region. Technical experts and the materials listed in the bibliography were consulted to assess both the range of values and to explore the relationships across regions, tree species and risk types. There were significant gaps in the availability of conclusive and specifically relevant scientific and insurance data to establish definitive assurance factor.

Based on an analysis of the available data, the range of data available provided a reasonable basis for concluding that over a creditable life of an afforestation project, considering cross-subsidy effects across regions and species, that a reasonable assurance factor would be greater than 90%. As the effects of many of these events would be captured in the assessment of above ground biomass accumulation over a given period, this appears to be a reasonable factor. However, there was not sufficient data to support refining this estimate above this level at this time, and as such, a 90% assurance factor was deemed reasonable.

Further research would be useful in supporting this assessment of an assurance factor and in refining the values by ecozone and tree species.

Primary Source Materials

W.J.A. Volney, R.I. Alfaro, P. Bothwell, E.H. Hogg, A. Hopkin, G. Laflamme, J.E. Hurley, G. Warren, J. Metsaranta and K.I. Mallett. 2005. A framework for poplar plantation risk assessments. Unasylva. No. 221. Vol. 56.

International Risk Management Group Ltd. 2005. RFP 05-0906: Report – Tasks` 1-4. Natural Resources Canada

International Risk Management Group Ltd. 2005. RFP 05-0906: Report – Tasks 5-9. Natural Resources Canada

APPENDIX C:
Quantification of Sequestration of Carbon

TABLE B1: Quantification Procedures for Flexibility Mechanisms

1.0 Project/ Baseline SS	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Contingency Method	6. Frequency	7. Justify measurement or estimation and frequency
Flexibility Mechanisms						
P7 Soil Organic Carbon Reservoir	$Sequestration_{Soil\ Organic\ Carbon} = Depth_{Soil} * \rho_{Bulk} * Concentration\ Change_{Carbon} * Area_{Afforested} * Conversion\ Factor_{C\text{-}CO2} * 10$					
	Sequestration $_{Soil\ Organic\ Carbon}$	kgs of CO_{2E}	N/A	N/A	N/A	Quantity being calculated.
	Soil Sample Depth / Depth $_{Soil}$	m	Measured	Based on sampling technique or tool.	Annual or Upon Chosen Crediting Interval	Standard method.
	Bulk Density / ρ_{Bulk}	g/m3	Measured	Laboratory analysis of statistically relevant number of samples.	Annual or Upon Chosen Crediting Interval	Standard method of laboratory analysis.
	Concentration Change in Soil Carbon Levels	%	Measured	Laboratory analysis of statistically relevant number of samples.	Annual or Upon Chosen Crediting Interval	Standard method of laboratory analysis.
	Area of Afforestation Project / Area $_{Afforested}$	ha	Estimated	Field survey or map-based assessment.	Annual or Upon Chosen Crediting Interval	Estimation can be made with high level of accuracy.
	Conversion factor for Carbon to Carbon Dioxide / Conversion Factor $_{C\text{-}CO2}$	-	Estimated	IPCC standard of 44/12.	Annual	Reference value.

TABLE B2: Contingent Data Collection Procedures for Flexibility Mechanisms

1.0 Project/ Baseline SS	2. Parameter / Variable	3. Unit	4. Measured / Estimated	5. Method	6. Frequency	7. Justify measurement or estimation and frequency
Flexibility Mechanisms						
P7 Soil Organic Carbon Reservoir	$Sequestration_{Soil\ Organic\ Carbon} = Depth_{Soil} * \rho_{Bulk} * Concentration\ Change_{Carbon} * Area_{Afforested} * Conversion\ Factor_{C\text{-}CO2} * 10$					
	Soil Sample Depth / $Depth_{Soil}$	m	Estimated	Select same as last measurement interval.	Annual or Upon Chosen Crediting Interval	Likely to stay constant over time.
	Bulk Density / ρ_{Bulk}	g/m3	Estimated	Extrapolation of previous measurements over time.	Annual or Upon Chosen Crediting Interval	Applicable in cases where there is a short interval since last estimate and more than 3 previous estimates.
	Concentration Change in Soil Carbon Levels	%	Estimated	Extrapolation of previous measurements over time.	Annual or Upon Chosen Crediting Interval	Applicable in cases where there is a short interval since last estimate and more than 3 previous estimates.
	Area of Afforestation Project / $Area_{Afforested}$	ha	Estimated	Aerial photographs	Annual or Upon Chosen Crediting Interval	Similar estimation technique with minor increase in uncertainty.